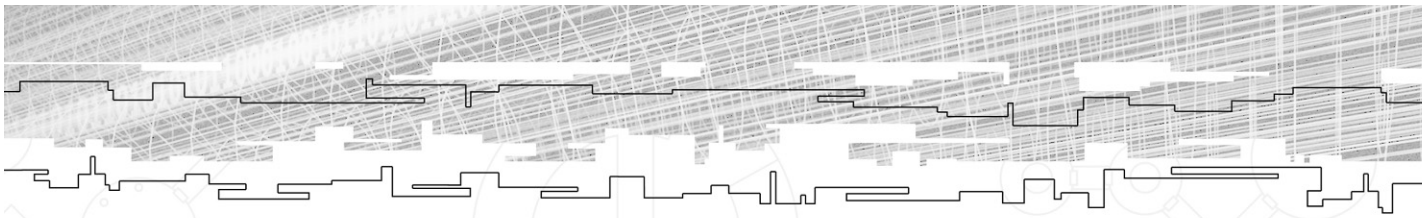
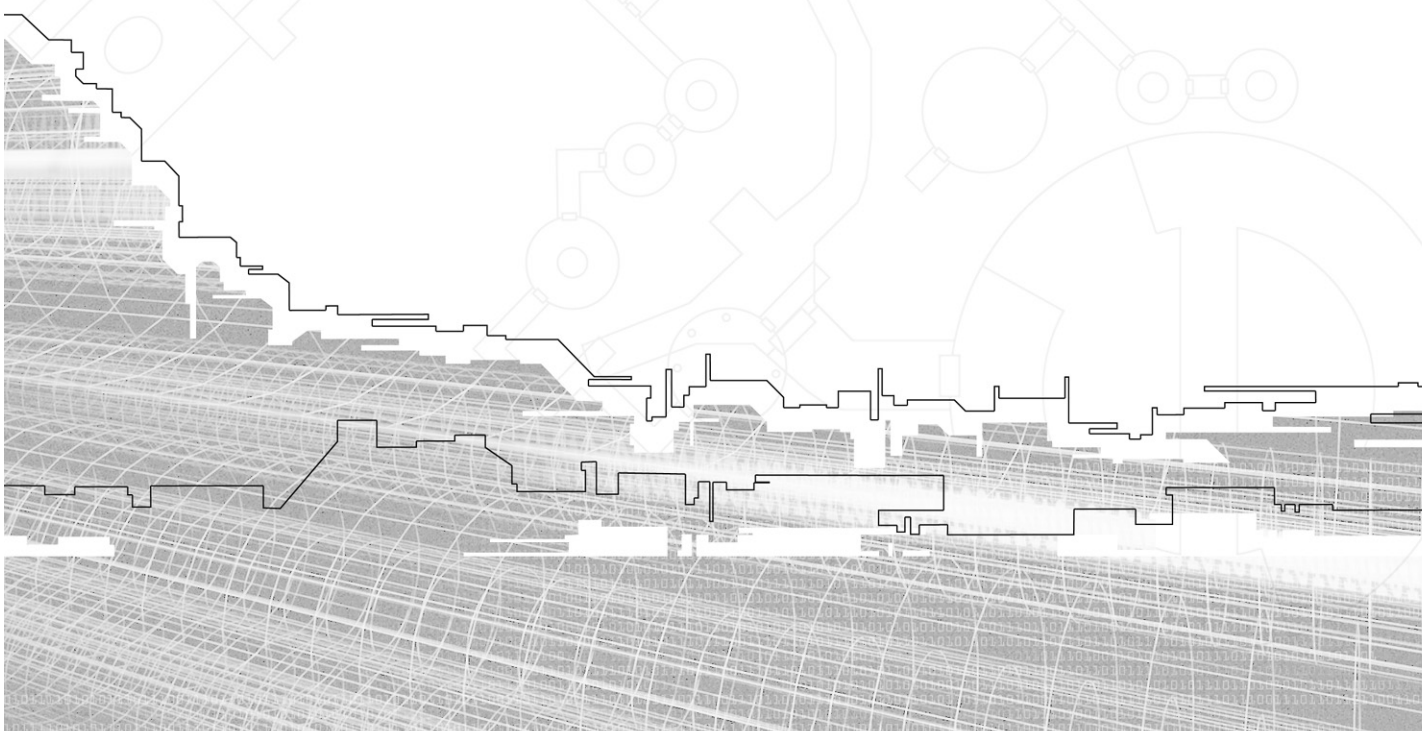


CHAPTER 7

GETTING SPECIFIC WITH GAMES IN LUA



The plainest sign of wisdom is a continual cheerfulness: her state is like that of things in the regions above the moon, always clear and serene.

—Michel de Montaigne

In this chapter, you'll push the boundaries of Lua and examine game programming itself—with some help from LuaSDL. I'll also launch into the Lua C API in this chapter.

LuaSDL

LuaSDL is Simple DirectMedia Layer's binding into the Lua universe. LuaSDL has its own project page on Sourceforge, at http://sourceforge.net/projects/luasdl/. Lua users also keep a copy of the distribution on their Wiki pages, at http://lua users.org/wiki/LuaModuleLuaSdl.

You can also find a copy of LuaSDL in the Chapter 7 section of this book's CD. The LuaSDL binaries are taken from Lua users.org and precompiled and generated by Thatcher Ulrich, a programmer for Oddworld Inhabitants. Thatcher's latest LuaSDL versions can be found at his Website, at http://tulrich.com.

In Windows, you need to place the prebuilt luaSDL.dll somewhere in your path in order for SDL to function. The easiest way to do this is to drop the luaSDL.dll into your Windows system folder. Linux-platform users also need to set the path or place libluaSDL.so into their library-loading path file (which varies; usually usr/lib or usr/local/lib). Only the pre-built binaries are available at the time of this writing, and they are only available on these platforms.

TIP

If you really want to get up-to-speed with SDL, check out the highly rated *Focus on SDL*, by Ernest Pazera, published by Premier Press.

Gravity: A Lua SDL Game

I first introduced SDL way back in Chapter 4, where you used it with Python to do some pretty amazing stuff. Lua's SDL bindings aren't quite as complete, and unfortunately they are also a little out-of-date. The bindings are still in beta (Version 0.3 as of this writing) and were put together using the Lua 4 interpreter (the binary module has been pre-packaged with the `toLua` tool). Because of this, all of the necessary Lua scripts are bundled with the game inside the folder (so you don't try running it with Lua 5).

LuaSDL comes bundled with a 2D sprite game prototype called *Meteor Shower*. The game is written entirely in Lua and SDL by Thatcher Ulrich, who has generously given the source code to the public domain. I use this code as a base for *Gravity*. The entire source sample can be found in the Gravity folder in the Chapter 7 section on the CD, along with the pre-compiled DLLs necessary to use SDL and the Lua 4 interpreter.

You can launch *Gravity* from the command line; just navigate to the directory using the command line and type:

```
Lua Gravity.lua
```

In *Gravity*, the player is the moon in a universe gone haywire. Planetary objects and space travelers zoom across the screen, each attracted to themselves and to the player by their given mass (see Figure 7.1). The player must avoid these objects or face destruction.

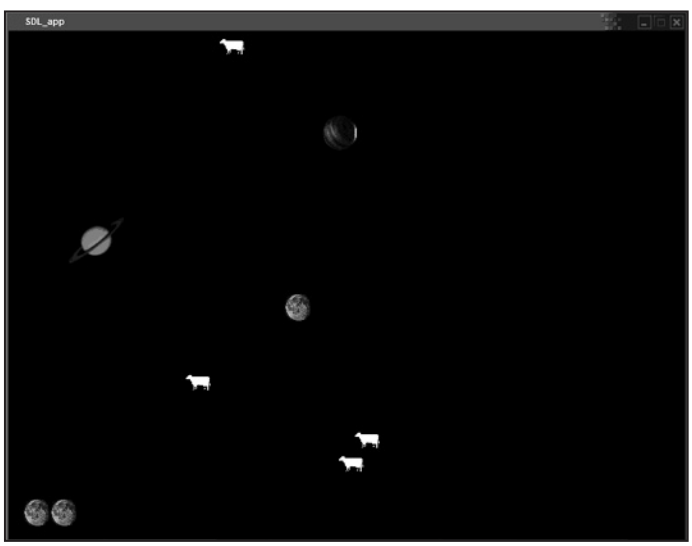


Figure 7.1

Gravity goes haywire in this LuaSDL game

A number of functions keep *Gravity* going. The list of functions for *Gravity* is shown in Figure 7.2.

Importing SDL

Before other code can start working, the program must have access to LuaSDL. This can be achieved with only a few short lines:

```
-- Need to load the SDL module
if loadmodule then
        loadmodule("SDL")
end
```

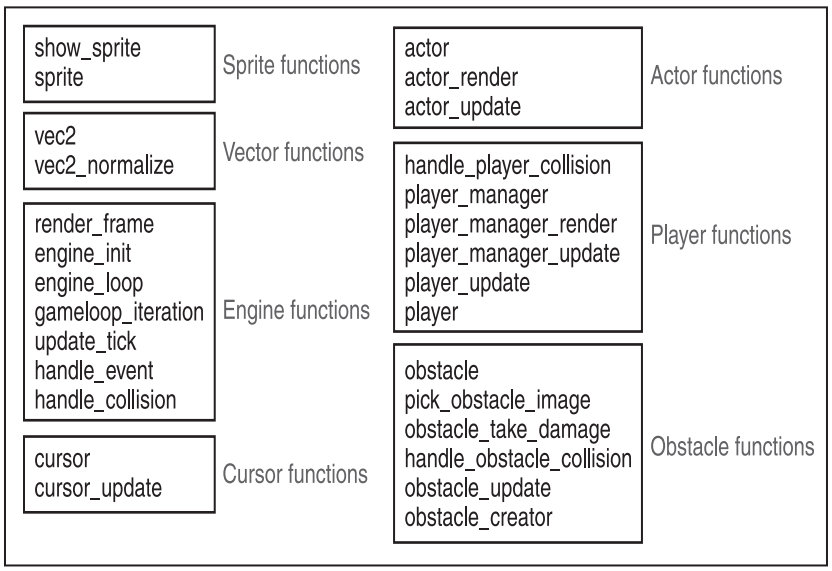


Figure 7.2

The function list for Gravity

Lua 5 versus Lua 4

Lua 5.0 was released early in April of 2003. A number of new features came with Lua 5.0, including the following:

- Coroutines for executing many independent threads.
- Block comments for having multiple comment lines in code.
- Boolean types for true and false.
- Changes to how the API loads chunks. This is supported by new commands: `lua_load`, `luaL_loadfile`, and `luaL_loadbuffer`.
- Lightweight userdata that holds a value and not an object.
- Weak tables that assist with garbage collection.
- A faster virtual machine that is register-based.
- Standard libraries that use namespaces, although basic functions are still global.
- New methods of garbage collection, such as metamethods and other new features that make collection safe.

Along with the added features came a number of incompatibilities with previous Lua versions. Watch out for the following differences if you are a Lua 4.0 guru moving to Lua 5.0:

Continued

- Metatables have replaced the tag-method scheme.
- There are a number of changes to function calls.
- There are new reserved words (including `false` and `true`).
- Most library functions are now defined inside Lua tables.
- `lua_pushuserdata` is deprecated and has been replaced with `lau_newuserdata` and `lua_pushlightuserdata`.

Work on 5.1 has already begun, and the rumor mill has it that this next version may be available by the end of 2003.

Setting Initial Variables

You must initialize a blit surface and a start gamestate early on for this 2D game.

Blitting, as you may recall from Chapter 4, is basically rendering or drawing, and in particular is the act of redrawing an object by copying the pixels of an object onto the screen.

An SDL blit surface looks like this:

```
SDL.SDL_BlitSurface = SDL.SDL_UpperBlit;
```

The `gamestate` is a collection of state variables, assigned to a Lua table, that are initialized before the game starts to run. These are listed in Table 7.1.

```
gamestate = {
        last_update_ticks = 0,
        begin_time = 0,
        elapsed_ticks = 0,
        frames = 0,
        update_period = 30,     -- interval between calls to update_tick
        active = 1,
        new_actors = {},
        actors = {},
        add_actor = function(self, a)
                assert(a)
                tinsert(self.new_actors, a)
        end
}
```

In this table there are a number of variables set to 0 and also a few nested tables. The `update_period` is the interval in milliseconds between calls to the update tick, and `active` is a Boolean that says whether the engine is currently active or not. The `add_actor` function is also defined in this table.

TABLE 7.1 The `gamestate` Variables

Element	Value
`last_update_ticks`	0
`begin_time`	0
`elapsed_ticks`	0
`frames`	0
`update_period`	30
`active`	1
`new_actors`	Nested table
`actors`	Nested table
`add_actor`	Function

The next Lua table is for a sprite cache. This cache will hold sprites that have already been loaded, so the engine won't have to try and load them on-the-fly:

```
sprite_cache = {}
```

Gravity is all about speed and velocity and, well, gravity. I envisioned flying planetary objects, each with different masses, bumping and colliding with each other in a solar system-like playing screen. To achieve this effect, I have to set gravity, how often obstacles fly onto the screen, and how many lives the player will have.

```
-- Set gravity
GRAVITY_CONSTANT = 100000
-- table of virtual masses for the different obstacle sizes
obstacle_masses = { 10, 50, 75 }
OBSTACLE_RESTITUTION = .05
-- soft speed-limit on obstacles
SPEED_TURNOVER_THRESHOLD = 4000
-- player manager actor
MOONS_PER_GAME = 3
--How often till new obstacle appears
BASE_RELEASE_PERIOD = 500
```

The three obstacles, two planets and a space cow, are illustrated in Figure 7.3. Each will use a unique bitmap image that is already included in the *Gravity* folder. These images are placed into a Lua table.

```
--load the bitmap obstacle images
obstacle_images = {
        { "obstacle1.bmp" },
        { "obstacle2.bmp" },
        { "obstacle3.bmp" },
}
```

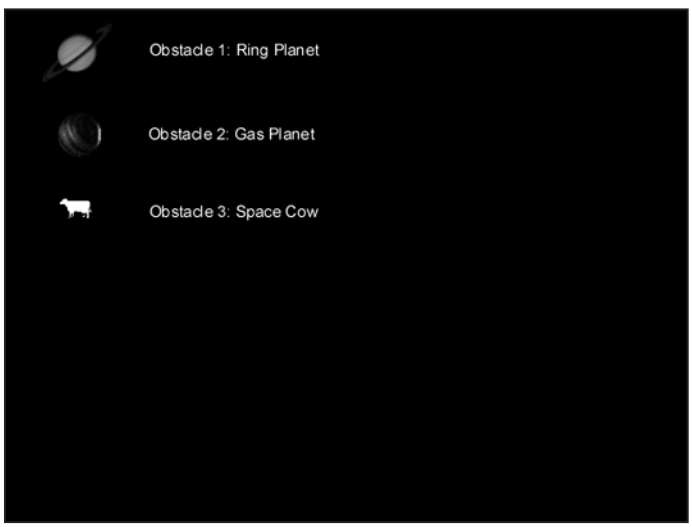


Figure 7.3

The three obstacles in Gravity

Creating Functions

Creating functions is really the meat and gravy of the endeavor. You need functions, lots of functions. Sprites, vectors, events, the game engine, and each actor (or object) within the game must be handled.

Sprite Handling

Sprite handling is the first thing to tackle (see Figure 7.4). The main sprite function will be a constructor that takes in a bitmap file and returns an SDL surface that can be blitted and used by the engine. A function that draws the new blitted SDL surface sprite onto a `rect` (`rects` are again from Chapter 4—they are the basic object for a 2D SDL game) will be part of the process as well. The main sprite function will be `sprite()`:

```
function sprite(file)
-- The sprite constructor. Passes in a bitmap filename and returns an SDL_Surface
        --First check the cache
        if sprite_cache[file] then
                return sprite_cache[file]
        end
```

```
        local temp, my_sprite;
        -- Load the sprite image
        my_sprite = SDL.SDL_LoadBMP(file);
        if my_sprite == nil then
                print("Couldn't load " ..  file .. ": " .. SDL.SDL_GetError());
                return nil
        end
        -- Set colorkey to black (for transparency)
        SDL.SDL_SetColorKey(my_sprite, SDL.bit_or(SDL.SDL_SRCCOLORKEY, SDL.SDL_RLEACCEL), 0)
        -- Convert sprite to video SDL format
        temp = SDL.SDL_DisplayFormat(my_sprite);
        SDL.SDL_FreeSurface(my_sprite);
my_sprite = temp;
        sprite_cache[file] = my_sprite
        return my_sprite
end
```

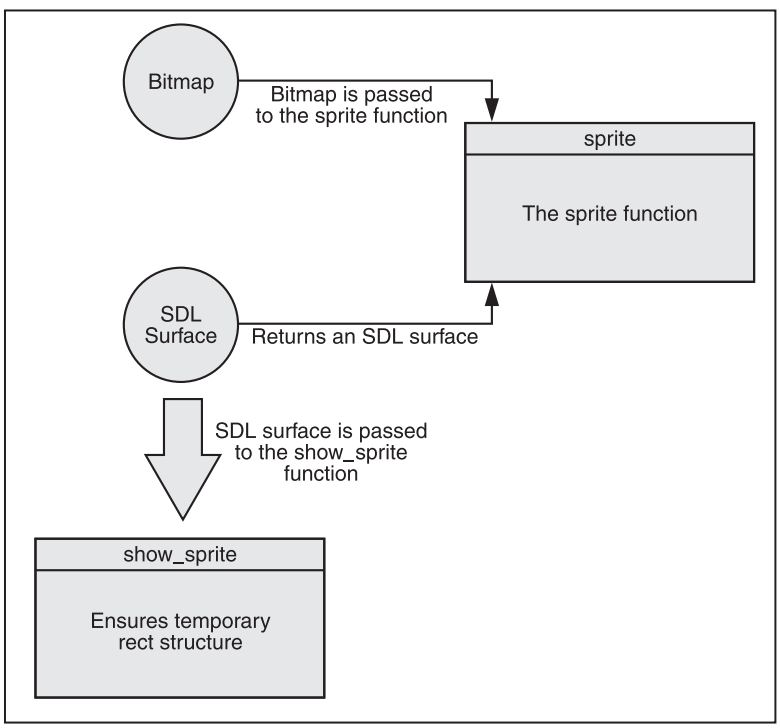


Figure 7.4

Sprite handling functions in Gravity

The sprite constructor first checks to make sure that the sprite doesn't already exist in `sprite_cache`. If it does not, the constructor tries to find the given BMP image file. If the file doesn't exist, the constructor exits with an error; otherwise it goes ahead and loads the image into an SDL format (using a `temp` variable as interim), sets the `colorkey` (another Chapter 4 concept), loads the sprite into the `sprite_cache`, and returns the sprite.

The second sprite function, `show_sprite`, is passed a sprite and draws it on the screen at the given coordinates (x,y). It uses the massively powerful `rect()` to accomplish this. Notice that in order for `show_sprite` to work, it needs all four variables:

```
function show_sprite(screen, sprite, x, y)
        -- make sure we have a temporary rect structure
        if not temp_rect then
                temp_rect = SDL.SDL_Rect_new()
        end
        temp_rect.x = x - sprite.w / 2
        temp_rect.y = y - sprite.h / 2
        temp_rect.w = sprite.w
        temp_rect.h = sprite.h
        SDL.SDL_BlitSurface(sprite, NULL, screen, temp_rect)
end
```

Vector Handling

When used in game physics, vectors combine magnitude (speed) and direction (see Figure 7.5). Vectors are extremely useful, as the engine needs to know the speed and direction of the objects and actors flying around the screen. In order to do this, the `vec2` function needs to take in a table and do some math.

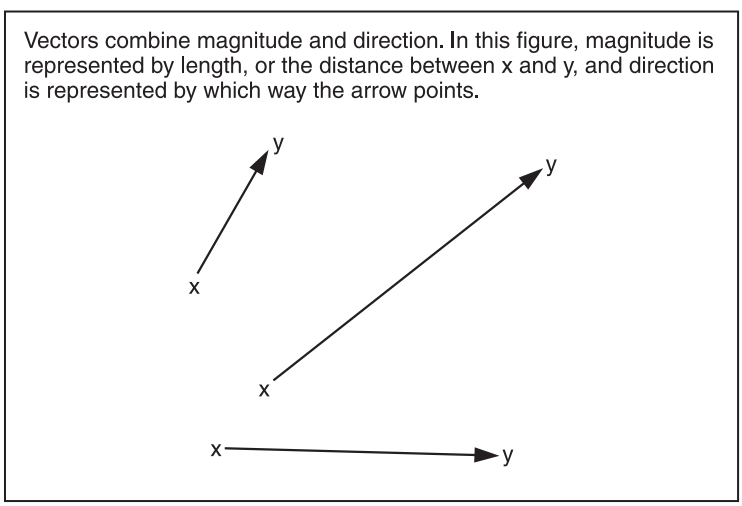


Figure 7.5

Vectors in physics combine magnitude and direction.

In geometry, vectors consist of a point or a location in space, a direction, and distance. The combination of direction and distance is sometimes called *displacement*. The `vec2` function helps to keep track of vectors using x and y coordinates, as shown in Figure 7.6. The starting coordinates are `a.x` and `a.y`, and the ending coordinates are `b.x` and `b.y`.

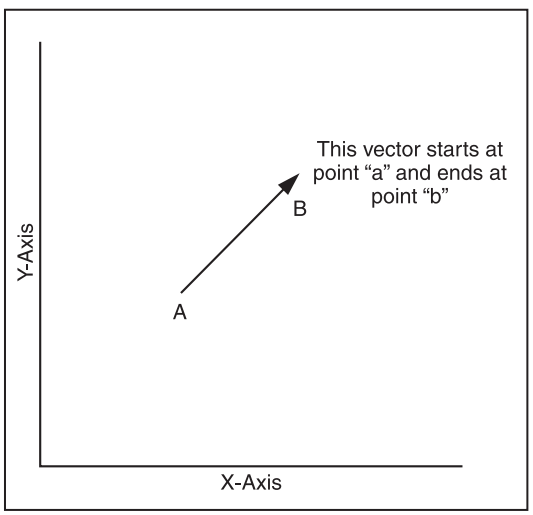


Figure 7.6

Starting and ending points of a vector

The `vec2` function has a number of methods for determining speed and direction of an actor or object using vectors. The `add`, `sub`, `mul`, and `unm` methods are used to track position in two-dimensional space by performing sector arithmetic.

The `add` method is used to do vector addition where the results of two vectors can be plotted in two-dimensional space, as shown in Figure 7.7. Vector subtraction is handled by the `sub` method, and does the opposite of vector addition by delivering the difference between two vectors.

You can multiply a vector by a constant to produce a second vector that travels in the same or the opposite direction but at a different speed. Multiplying vectors in math is called *scalar multiplication*. Scalar multipication can be really useful for collisions—say if two planets in the *Gravity* game collide, and they need to bounce off of each other in opposite directions.

There is also a second way of multiplying vectors that gives the angle between two vectors. This called the *dot product*; it is also handled by the `mul` method. Although you don't use the dot product in this game, it is a useful vector function and is sometimes used to perform lighting calculations (say, if you wanted to add a sun object that casts shadows to the game) or determine facing in 3D games.

After running through `vec2`, `vec2_normalize` finishes the vector math by dividing by the length and catching any possible close to 0 calculations that could cause errors.

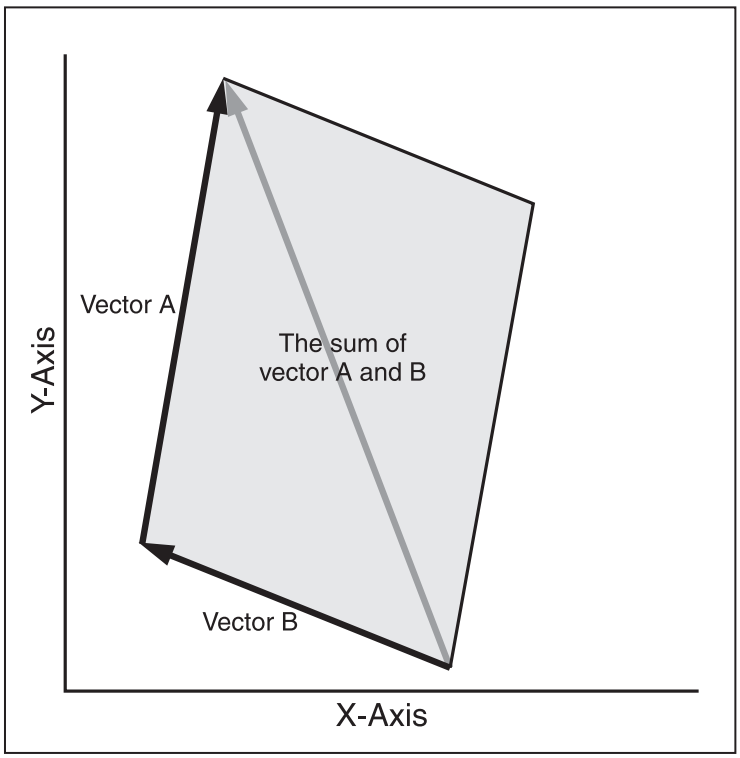


Figure 7.7

Vector addition

```
--vec2_tag = nil
-- re-initialize the vector type when reloading
function vec2(t)
-- constructor
        if not vec2_tag then
                vec2_tag = newtag()
                Vector addition
                settagmethod(vec2_tag, "add",
                        function (a, b) return vec2{ a.x + b.x, a.y + b.y } end
                )
                Vector subtraction
                settagmethod(vec2_tag, "sub",
                        function (a, b) return vec2{ a.x - b.x, a.y - b.y } end
                )
                Vector multiplication
                settagmethod(vec2_tag, "mul",
                        function (a, b)
                                if tonumber(a) then
                                        return vec2{ a * b.x, a * b.y }
```

```
                elseif tonumber(b) then
                        return vec2{ a.x * b, a.y * b }
                else
                        -- dot product.
                        return (a.x * b.x) + (a.y * b.y)
                end
        end
    )
    settagmethod(vec2_tag, "unm",
        function (a) return vec2{ -a.x, -a.y } end
    )
end

local v = {}
if type(t) == 'table' or tag(t) == vec2_tag then
    v.x = tonumber(t[1]) or tonumber(t.x) or 0
    v.y = tonumber(t[2]) or tonumber(t.y) or 0
else
    v.x = 0
    v.y = 0
end
settag(v, vec2_tag)
v.normalize = vec2_normalize
return v
end

function vec2_normalize(a)
-- If a has 0 or near-zero length, sets a to an arbitrary unit vector
local d2 = a * a
if d2 < 0.000001 then
    -- Return arbitrary unit vector
    a.x = 1
    a.y = 0
else
    -- divide by the length to get a unit vector
    local length = sqrt(d2)
    a.x = a.x / length
    a.y = a.y / length
end
end
```

Event Handling

Handlers for key presses and mouse clicks are necessary for any computer game. Mouse events will be picked up by the individual actor that controls the player, but monitoring for the keyboard and windows events must also occur in case a player wants to close a window

or quit using the Escape key. This can be done fairly easily (see Figure 7.8) by using `SDL_KEYDOWN` to watch for `SDLK_q` or `SDLK_ESCAPE`.

```
function handle_event(event)
-- called by main loop
--Checks for keypresses
-- sets gamestate to nil if player wants to quit
        if event.type == SDL.SDL_KEYDOWN then
                local   sym = event.key.keysym.sym
                if sym == SDL.SDLK_q or sym == SDL.SDLK_ESCAPE then
                        gamestate.active = nil
                end
        elseif event.type == SDL.SDL_QUIT then
                gamestate.active = nil
        end
end
```

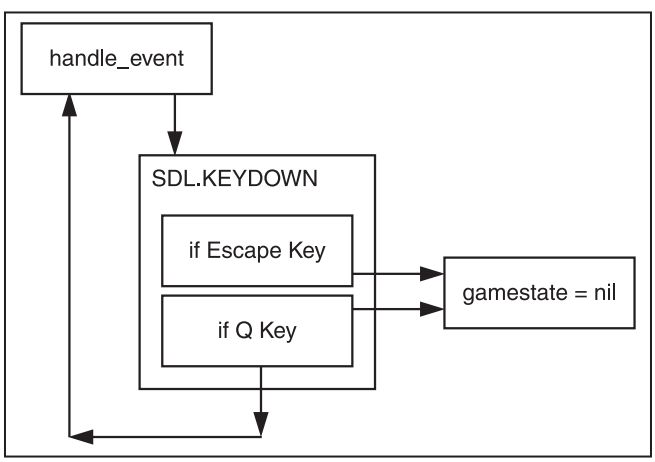


Figure 7.8

Event handling

The Engine and the Game Loop

A number of actions must happen in the engine and game loop, and these actions should correspond to a codeable function. You must have a function to remove any sprites that aren't being used and add any new ones, a function to render the screen and background, a function that keeps track of time and updates the game state, a function that does the blitting, and a function that listens for player keystrokes:

- **`render_frame.`** Updates and redraws.
- **`engine_init.`** Sets screen and video.
- **`engine_loop.`** Main engine loop.
- **`gameloop_iteration.`** Tracks time and call other functions.

- **update_tick.** Updates any game actors.
- **handle_event.** Listens for any events caused by the player.
- **handle_collision.** Handles any actor collisions.

The first step is to initialize the engine.

The `engine_init` function is used to set the screen width and height and the video mode and to start the game ticking, so to speak. It does all this through common-sense local variables, a few SDL calls, and calling `gamestate`:

```
function engine_init(argv)
        local width, height;
        local video_bpp;
        local videoflags;
        videoflags = SDL.bit_or(SDL.SDL_HWSURFACE, SDL.SDL_ANYFORMAT)
        width = 800
        height = 600
        video_bpp = 16
        -- Set video mode
        gamestate.screen = SDL.SDL_SetVideoMode(width, height, video_bpp, videoflags);
        gamestate.background = SDL.SDL_MapRGB(gamestate.screen.format, 0, 0, 0);
        SDL.SDL_ShowCursor(0)
        -- initialize the timer/ticks
        gamestate.begin_time = SDL.SDL_GetTicks();
        gamestate.last_update_ticks = gamestate.begin_time;
end
```

Removing any actors that are no longer used and adding any new actors is handled by an `update_tick` function. Two Lua `for` loops iterate through each actor in the game. The first removes any actors that aren't active and adds any new ones:

```
for i = 1, getn(gamestate.actors) do
        if gamestate.actors[i].active then
                        -- add the actors
                        tinsert(gamestate.new_actors, gamestate.actors[i])
        end
end
```

The former `gamestate.actor` table is then replaced with the new table in a quick swap:

```
gamestate.actors = gamestate.new_actors
gamestate.new_actors = {}
```

Then a second `for` loop calls an update for each actor in the table:

```
-- call update for each actor
        for i = 1, getn(gamestate.actors) do
                gamestate.actors[i]:update(gamestate)
        end
```

After the actors have been updated, each needs to be redrawn, as does the screen. A quick `render_frame` function does this work, first clearing the current screen and then redrawing each actor `rect()` within `gamestate.actors`:

```
function render_frame(screen, background)
-- When called renders a new frame.
        -- First clears the screen
        SDL.SDL_FillRect(screen, NULL, background);
        -- re-draws each actor in gamestate.actors
        for i = 1, getn(gamestate.actors) do
                gamestate.actors[i]:render(screen)
        end
        -- updates
        SDL.SDL_UpdateRect(screen, 0, 0, 0, 0)
end
```

Most of the actual game-engine work is done by this next little function, called `gameloop_iteration`. It is called each time the engine loops, and is responsible for calling all the other rendering functions and keeping track of time. First `gameloop_iteration` calls `handle_event` on any pending events in the gamestate's `event_buffer` (checking first that the buffer exists):

```
function gameloop_iteration()
-- call this to update the game state.  Runs update ticks and renders
-- according to elapsed time.
        -- if buffer doesnt exist make it so
        if gamestate.event_buffer == nil then
                gamestate.event_buffer = SDL.SDL_Event_new()
        end
        -- run handle_even on any pending events
        while SDL.SDL_PollEvent(gamestate.event_buffer) ~= 0 do
                handle_event(gamestate.event_buffer)
        end
```

`gameloop_iteration` then uses `SDL_GETTICKS()` to set the `local time` variable and compares this with the `gamestate` to see if an update needs to occur. If the engine needs to update, then `update_tick` is called and the time count is updated:

```
-- run any necessary updates
        local time = SDL.SDL_GetTicks();
        local delta_ticks = time - gamestate.last_update_ticks
        local update_count = 0
        while delta_ticks > gamestate.update_period do
                update_tick();
                delta_ticks = delta_ticks - gamestate.update_period
                gamestate.last_update_ticks = gamestate.last_update_ticks +
```

```
gamestate.update_period
                update_count = update_count + 1
        end
```

Finally, `render_frame` has to be called to redraw any actors and the screen background if an update has occurred:

```
-- if we did any updates, then render a frame
        if update_count > 0 then
                render_frame(gamestate.screen, gamestate.background)
                gamestate.frames = gamestate.frames + 1
        end
end
```

The actual engine game loop (`engine_loop`) runs while the `gamestate` is active. The `engine_loop` calls `gameloop_iteration` each time its own `while` loop fires. The `engine_loop` then cleans out the buffer. If the `gamestate` is no longer active, then `engine_loop` calls `SDL_QUIT`:

```
function engine_loop()
-- While loop calls gameloop_iteration
        while gamestate.active do
                gameloop_iteration()
        end
        -- clean up
        if event_buffer then
                SDL.SDL_Event_delete(event)
        end
        SDL.SDL_Quit();
end
```

Actors

Everyone wants to be an actor—or a computer game programmer—these days. Actors in *Gravity* aren't as revered or lucky as the Hollywood variety, however. They are the constructs that can be interacted with in the game, as shown in brief in Figure 7.9. These base actor functions will be used by the other objects in the game.

Learning how to update an actor's position on the screen is the first task here, and this is where the vector functions get to stretch their legs. Velocity is multiplied by how much time has elapsed in the `gamestate` loop since the last update:

```
function actor_update(self, gs)
-- Updates than actor using vector functions
        local   dt = gamestate.update_period / 1000.0
        -- update according to velocity & time
        local   delta = self.velocity * dt
        self.position = self.position + delta
```

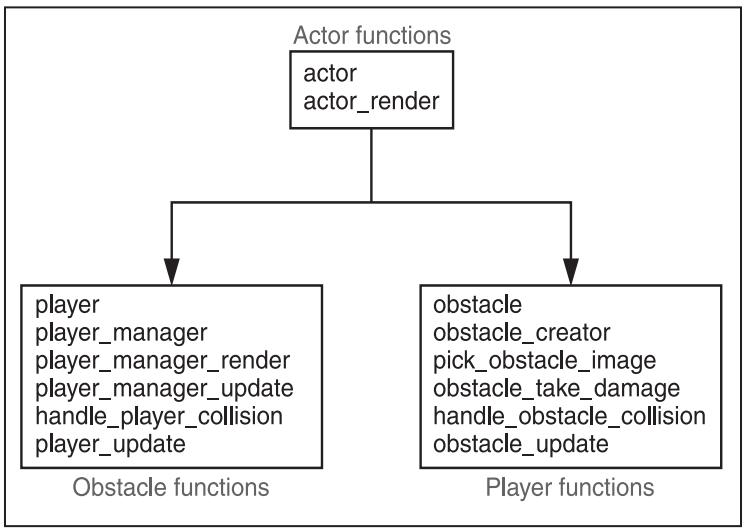


Figure 7.9

Actors are initialized in Gravity

Since this is a 2D *Asteroids*-type game, objects on the screen should wrap around to the other side when they hit an edge. This effect is achieved with simple math applied to the position and the game screen (`gs.screen`) before `actor_update` ends:

```
-- wrap around at screen edge
        if self.position.x < -self.radius and self.velocity.x <= 0 then
                self.position.x = self.position.x + (gs.screen.w + self.radius * 2)
        end
        if self.position.x > gs.screen.w + self.radius and self.velocity.x >= 0 then
                self.position.x = self.position.x - (gs.screen.w + self.radius * 2)
        end
        if self.position.y < -self.radius and self.velocity.y <= 0 then
                self.position.y = self.position.y + (gs.screen.h + self.radius * 2)
        end
        if self.position.y > gs.screen.h + self.radius and self.velocity.y >= 0 then
                self.position.y = self.position.y - (gs.screen.h + self.radius * 2)
        end
end
```

A function that blits actors onto the screen using `show_sprite` is the next thing to create after determining the actor's position:

```
function actor_render(self, screen)
-- Blit the given actor to the given screen
        show_sprite(screen, self.sprite, self.position.x, self.position.y)
end
```

The final curtain on actors is to build an actor constructor. The constructor will take in the sprite bitmap and keep track of position, velocity, and radius, and then return the actor in a nice, neat Lua table:

```
function actor(t)
-- actor constructor.  Pass in the name of a sprite bitmap.
        local a = {}
        -- copy elements of t
        for k,v in t do
                a[k] = v
        end
        a.type = "actor"
        a.active = 1
        a.sprite = (t[1] or t.sprite and sprite(t[1] or t.sprite)) or nil
        a.position = vec2(t.position)
        a.velocity = vec2(t.velocity)
        a.radius = a.radius
                or (a.sprite and a.sprite.w * 0.5)
                or 0
        a.update = actor_update
        a.render = actor_render
        return a
end
```

Obstacles

The game obstacles are cows and planets. These obstacles must track a number of different things in order to make the game interesting.

- Obstacles can take damage. Some of the bigger objects will survive collisions with several smaller objects, so they need to track how much damage they can take.
- Obstacles need to know when they collide with something.
- Obstacles are drawn to each other by gravity, and so they need to keep track of other nearby obstacles.

Obstacles should also occasionally appear on the screen. They should come from offscreen at a random place, at a random speed, and travel somewhat towards the center of the screen. These object capabilities are handled with the following functions:

- **`obstacle_update()`**. Handles gravity, movement, and collisions.
- **`handle_obstacle_collision()`**. Called when a collision is detected.
- **`obstacle_take_damage()`**. Damages the object.
- **`pick_obstacle_image()`**. Chooses one of the obstacle images at random.
- **`obstacle()`**. The obstacle constructor.
- **`obstacle_creator()`**. Randomly places obstacles onto the screen.

The `obstacle_update` is the first function to tackle. It watches for collisions by first updating itself and then keeping track of where the other actors are:

```
function obstacle_update(self, gs)
-- update this obstacle.  watch for collisions with other actors.
        -- move ourself
        actor_update(self, gs)
        local   dt = gamestate.update_period / 1000
        local   accel = vec2()
        -- check for the position of other actors
        for i = 1, getn(gs.actors) do
                local   a = gs.actors[i]
```

Actors with a large mass will draw other actors towards themselves. This is simulated with the `GRAVITY_CONSTANT`, the two actors' mass, and some math.

The Newtonian concept of attraction takes the mass of two objects, the distance between them, and the constant of gravity to determine how strong the attraction is between the two objects (see Figure 7.10).

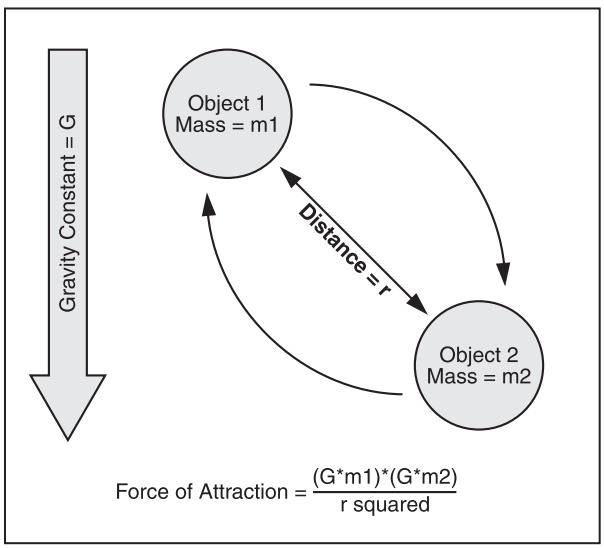


Figure 7.10

Newton's law of attraction (i.e. universal gravitation*)*

This law is usually expressed by (G*m1)*(G*m2)/r^2, where G is the gravitational constant, m1 is the mass of the first object, m2 is the mass of the second object, and r is the distance between the two objects.

This formula is used in `obstacle_update` by taking the `GRAVITY_CONSTANT` and the mass of an object (`a.mass`) and accelerating actors towards other actors:

```
-- if the actor has mass then compute a gravitational acceleration towards it
        if a.mass then
                local r = a.position - self.position
                local d2 = r * r
```

```
                if d2 < 100 * 100 then
                        local d = sqrt(d2)
                        if d * 2 > self.radius then
                            accel = accel + r * ((GRAVITY_CONSTANT * a.mass) / (d2 * d))
                        end
                end
        end
```

Then `obstacle_update` needs to check for actual collisions and handle them by calling `handle_collision`. You end the function by resetting the actor's velocity:

```
        -- check for collisions, and respond
                if a and a ~= self and a.collidable then
                        local disp = a.position - self.position
                        local distance_squared = disp * disp
                        local sum_radius_squared = (a.radius + self.radius) ^ 2
                        if distance_squared < sum_radius_squared then
                                -- we have a collision, call the collision handler.
                                handle_collision(self, a)
                        end
                end
        end
        self.velocity = self.velocity + accel * dt
end
```

The next function, `handle_obstacle_collision`, fires when the obstacles collide. It first makes sure that the collision is between two obstacles and not between an obstacle and the player; that would be handled by a different function. It then damages the objects that collide by calling `obstacle_take_damage`:

```
function handle_obstacle_collision(a, b)
-- handles a collision between two obstacles, a and b.
        --Make sure we are handling collison between two obstacles, otherwise exit
        if a.type == "obstacle" and b.type == "obstacle" then
           -- impulse will be along the displacement vector between the two obstacles
           local normal = b.position - a.position
           normal:normalize()
           local relative_vel = b.velocity - a.velocity
           -- Damage the objects that collide
           local collision-energy = 0.1 * (relative_vel * realtive_ve;) * (a.mass + b.mass)
           local split_dir = vec2{ normal.y, -normal.x }
           obstacle_take_damage(a, split_dir, -normal, collision_energy)
           obstacle_take_damage(b, split_dir, normal, collision_energy)
        end
end
```

The `obstacle_take_damage` is called in the event of a collision. Some objects may survive a collision, but at least one (the one with lesser mass) will be destroyed. The smallest objects (cows) will always be destroyed:

```
function obstacle_take_damage(a, split_direction, collision_normal, collision_energy)
-- damage the obstacle; if it's damaged enough, destroy
        local split_speed = sqrt(2 * collision_energy / a.mass) * 0.35
        -- obstacle takes damage; when its damage reaches 0 it dies
        a.hitpoints = a.hitpoints - collision_energy / 2000
        if a.hitpoints > 0 then
                -- collision is not violent enough to destroy this obstacle
                return
        end

        local new_size = a.size - 1
        if new_size < 1 then
                -- The smallest obstacle always disintegrates.
                a.active = nil
                return
        end
        -- kill a
        a.active = nil
end
```

`Pick_obstacle_image` is a short random function that will pick which object to use from the `image_table` using Lua's built-in `random`:

```
function pick_obstacle_image(size)
        local image_table = obstacle_images[size]
        -- pick one of the obstacle images at random
        return image_table[random(getn(image_table))]
end
```

The `obstacle` constructor uses the `actor` constructor as its building block. It then sets its type to `"obstacle"`, flags it as collideable, makes sure it has one of the three obstacle sizes, and then sets variables for radius, size, and speed. It also assigns the obstacle to `obstacle_update`:

```
-- constructor
-- start with a regular actor
      local a = actor(t)
      a.type = "obstacle"
      a.collidable = 1
      a.size = a.size or 3        -- make sure caller defined one of the three sizes of obstacle
      a.sprite = sprite(pick_obstacle_image(a.size))
      a.radius = 0.5 * a.sprite.w
      a.mass = obstacle_masses[a.size]
      a.hitpoints = a.mass * a.mass
```

```
        -- implement a speed-limit on obstacles
        local   speed = sqrt(a.velocity * a.velocity)
        if speed > SPEED_TURNOVER_THRESHOLD then
                local new_speed = SPEED_TURNOVER_THRESHOLD + sqrt(speed -
SPEED_TURNOVER_THRESHOLD)
                a.velocity = a.velocity * (new_speed / speed)
        end
        -- attach the behavior handlers
        a.update = obstacle_update
        return a
end
```

Math functions like `sqrt()` have a reputation for being slow, especially when complex math has to be calculated on-the-fly. Having to process sudden large computations can cause an otherwise fluidly running game to grind to a halt. One way to speed up `sqrt` is to cache any square root values that are used more than once. Let's say you had the following code:

```
a* sqrt(s)
b* sqrt(s)
c =  a+b
```

Instead of running the `sqrt()` function twice, run it once first and store the value:

```
square = sqrt(s)
a*square
b*square
c = a+b
```

A second trick is to do common math ahead of time and place it in a table for the program. Let's say you did a log of power of multiplication in a program; you could work out common equations first and put them in a table like Table 7.2.

TABLE 7.2 Common Power

Initial Value	^2	^ 3
2	4	8
3	9	27
4	16	64
5	25	125
6	36	216

When the code needs one of these values, it gets a reference to the appropriate row and column instead of calculating on-the-fly.

The very last thing obstacles need to do is appear occasionally on the screen to harass the player. This is achieved by creating an actor that sets a countdown timer. When the timer reaches 0, the actor calls the obstacle construct, creates the obstacle on the edge of the screen, and sets it flying towards the middle somewhere. Then it starts the timer over again:

```
-- random obstacle creator
function obstacle_creator(t)
-- constructs an actor that randomly spawns a new obstacle periodically
        a = {}
        a.active = 1
        a.type = "obstacle_creator"
        a.collidable = nil
        a.position = vec2{ 0, 0 }
        a.velocity = vec2{ 0, 0 }
        a.sprite = nil
        -- set the random timer countdown
        a.period = t.period or t[0] or 100      -- period between spawning obstacles
        a.countdown = a.period
        a.render = function () end
        a.update =
                function (self, gs)
                        self.countdown = self.countdown - gs.update_period
                        if self.countdown < 0 then
                                -- timer has expired; spawn an obstacle
                                -- pick a random spot around the edge of the screen
                                local w, h = gs.screen.w, gs.screen.h
                                local edge = random(w * 2 + h * 2)
                                local pos
                                if edge < w then
                                        pos = vec2{ edge, 0 }
                                elseif edge < w*2 then
                                        pos = vec2{ edge - w, h }
                                elseif edge < w*2 + h then
                                        pos = vec2{ 0, edge - w*2 }
                                else
                                        pos = vec2{ w, edge - (w*2 + h) }
                                end
                                -- aim at the middle of the screen
                                local vel = vec2{ w/2, h/2 } - pos
                                vel:normalize()
                                vel = vel * (random(400) + 50)
                                gs:add_actor(
                                        obstacle{
                                                size = random(3),
```

```
                                        position = pos,
                                        velocity = vel
                                }
                        )
                        -- reset the timer
                        self.countdown = self.period
                end
        end
    return a
end
```

The Player

The player is arguably the most important game piece. Much of the infrastructure the player needs (such as sprite handling and actor functions) has already been laid out. However, you still need functions to handle the following:

- Updating the player
- Player collision
- The `player` constructor

The `player_updater` function handles updating the player; it looks similar to the `object_updater` function. The `player` object is handled just like an operating system's mouse cursor. The player's position is based on the mouse position. Using `SDL_GetMouseState`, the player position is updated, and checks for any collisions are made. If there is a collision, `handle_player_collision` is called:

```
function player_update(self, gs)
-- update the player and watch for collisions
        local   dt = gamestate.update_period / 1000
        -- get the mouse position, and move the player position towards the mouse position
        local   m = {}
        m.buttons, m.x, m.y = SDL.SDL_GetMouseState(0, 0)
        local   mpos = vec2{ m.x, m.y }
        local   delta = mpos - self.position
        local   accel =
                delta * 50      -- move towards the mouse cursor
                - self.velocity * 10    -- damping
        self.velocity = self.velocity + accel * dt
        -- move ourself
        actor_update(self, gs)
        -- check for collisions against all other actors
        for i = 1, getn(gs.actors) do
                local   a = gs.actors[i]
                -- check for collisions, and respond
                if a and a ~= self and a.collidable then
                        local disp = a.position - self.position
```

```
                        local distance_squared = disp * disp
                        local sum_radius_squared = (a.radius + self.radius) ^ 2
                        if distance_squared < sum_radius_squared then
                                -- we have a collision
                                -- call the collision handler.
                                handle_player_collision(self, a)
                        end
                end
        end
end
```

The `handle_player_collision` also looks quite a bit like the `handle_obstacle_collision`, except it's shorter because there is no concern over damage. A collision will kill the player by setting its `active` method to `nil`:

```
function handle_player_collision(a, b)
-- handles a collision between a player, a, and some other object, b
        -- impulse will be along the displacement vector between the two obstacle
        local normal = b.position - a.position
        normal:normalize()
        local relative_vel = b.velocity - a.velocity
        if relative_vel * normal >= 0 then
                -- don't do collision response if obstacles are moving away from each other
                return
        end
        -- Kill the player
        a.active = nil
end
```

The `player` constructor is similar to the other constructors that have been built, except that it's smaller. The actor template is used initially, then the constructor loads the moon.bmp as its image, sets itself as collideable, gives itself a mass (yes, the player's gravity attracts objects) and radius, and sets itself to run `player_update`.

```
function player(t)
-- constructor
        -- start with a regular actor
        local a = actor(t)
        a.type = "player"
        a.collidable = 1
        a.sprite = sprite("moon.bmp") -- or error("can't load ....")
        a.radius = 0.5 * a.sprite.w
        a.mass = 10
        -- attach the behavior handlers
        a.update = player_update
        return a
end
```

The `player` object needs a few utility functions with which to keep track of his lives and whether he's entered the game. The player cursor will have different visual states before the game starts, while playing, and after a collision, so these need to be kept track of as well. This is done with corresponding functions in the `player_manager`.

First is the `player_manager_update`. It keeps track of the player state, which is either pre-game or setup, active or playing, or deceased. If the player has died, `player_manager_update` checks to see if there are any lives left by checking the `MOONS_PER_GAME` constant. If there are, there is a short delay before the player can launch his next moon. These are all handled by a handful of Lua `if elseif then` statements:

```
function player_manager_update(self, gs)
-- keep track of game functions
        if self.state == "pre-setup" then
                -- delay, and then enter setup mode.
                self.countdown = self.countdown - gamestate.update_period
                if self.countdown <= 0 then
                        self.state = "setup"
                        self.cursor.active = 1
                        gamestate:add_actor(self.cursor)
                end
        elseif self.state == "setup" then
                if not self.cursor.active then
                        -- player has placed the moon.  start playing.
                        self.player.active = 1
                        self.player.position = self.cursor.position
                        gamestate:add_actor(self.player)
                        -- deduct the moon that we just placed.
                        self.moons = self.moons - 1
                        self.state = "playing"
                end
        elseif self.state == "playing" then
                if not self.player.active then
                        -- player has died.
                        if self.moons <= 0 then
                                -- game is over
                                self.state = "pre-attract"
                                self.countdown = 1000
                        else
                                -- set up for next moon
                                self.state = "pre-setup"
                                self.countdown = 1000
                        end
                end
        elseif self.state == "pre-attract" then
                -- delay, and then enter attract mode
                self.countdown = self.countdown - gamestate.update_period
```

```
                if self.countdown <= 0 then
                        self.state = "attract"
                end
        elseif self.state == "attract" then
                local m = {}
                m.buttons, m.x, m.y = SDL.SDL_GetMouseState(0, 0)
                if m.buttons > 0 then
                        -- start a new game.
                        self.state = "pre-setup"
                        self.moons = MOONS_PER_GAME

                        self.countdown = 1000
                end
        end
end
```

The function called `player_manager_render` comes in at this point to display moon sprites that show how many lives the player has left:

```
function player_manager_render(self, screen)
        if self.state == "attract" then
                show_sprite(screen, self.game_over_sprite, screen.w / 2, screen.h / 2)
        else
                -- show the moons remaining
                local sprite = self.player.sprite
                local x = sprite.w
                local y = screen.h - sprite.h
                for i = 1, self.moons do
                        show_sprite(screen, sprite, x, y)
                        x = x + sprite.w
                end
        end
end
```

The `player_manager` constructor is the last function you need to wrap up the player. Like the constructors, this function builds a Lua table that stores the variable you need, such as which player mouse curser you currently use, how many lives are left, and who to call for rendering and updating:

```
function player_manager(t)
-- constructor
        local a = {}
        for k, v in t do a[k] = v end   -- copy values from t
        a.active = 1
        a.moons = MOONS_PER_GAME
        a.state = "setup"
        a.cursor = cursor{
        }
```

```
        gamestate:add_actor(a.cursor)
        a.player = player{
                position = { gamestate.screen.w / 2, gamestate.screen.h / 2 },
                velocity = { 0, 0 },
        }
        a.obstacle_creator.period = BASE_RELEASE_PERIOD
        a.game_over_sprite = sprite("finish.bmp")
        a.update = player_manager_update
        a.render = player_manager_render
        return a
end
```

Starting the Game

Almost finished! Only a few functions remain. The mouse cursor must be properly tracked and you need a check for mouse buttons that will start gameplay. The mouse cursor is set initially to a start.bmp graphic that lets the player choose where to position the moon when in the playing window. All of these actions are accomplished with `cursor_update` and the `cursor` constructor, and all the information is held within Lua tables:

```
function cursor_update(self, gs)
-- update the cursor.  follow the mouse.
        local   m = {}
        m.buttons, m.x, m.y = SDL.SDL_GetMouseState(0, 0)
        self.position.x = m.x
        self.position.y = m.y
        if m.buttons ~= 0 then
                -- player has clicked
                self.active = nil
        end
end

function cursor(t)
-- constructor
        -- start with a regular actor
        local a = actor(t)
        a.type = "cursor"
        a.sprite = sprite("start.bmp") -- or error("can't load ....")
        a.radius = 0.5 * a.sprite.w
        -- attach the behavior handlers
        a.update = cursor_update
        return a
end
```

Initializing the game engine is a pretty straightforward endeavor after all the work that's already been done. The `engine_init` function is called, and a slew of obstacles are in the `gamestate` with `add_actor`:

```
engine_init{}
-- Generate a bunch of obstacles
for i = 1,10 do
        gamestate:add_actor(
                obstacle{
                        position = { random(gamestate.screen.w),
random(gamestate.screen.h) },
                        velocity = { (random()*2 - 1) * 100, (random()*2 - 1) * 100 },  -
- pixels/sec
                        size = random(3)
                }
        )
end
```

Then create an `obstacle_creator` and a `player_manager` and let them duke it out:

```
-- create an obstracle creator
creator = obstacle_creator{}
gamestate:add_actor(creator)
-- create a player manager
gamestate:add_actor(
        player_manager{
                obstacle_creator = creator
        }
)
```

Last but not least, call the `engine_loop()`, and lo-and-behold, the game is running:

```
-- run the game
engine_loop()
```

The Lua C API

Ah, the power of C. Anything that can be done directly in Lua can also be done in the Lua C API, including manipulating variables and tables, calling functions, controlling the garbage collector, or loading Lua from strings or files.

Typically, the Lua C library is compiled into an application or run as a shared library. This is the most common way of accessing Lua in a game program. Altogether, the Lua library is very small, so it is not uncommon to find the entire source tree included with a distributed game.

TIP

If you want to delve deeper into the C family, check out *C Programming for the Absolute Beginner*, by Michael Vine, or *C++ Programming for the Absolute Beginner*, by Dirk Henkemans and Mark Lee.

Opening Up Lua

Before calling any API function, a pointer to the Lua state must be passed as the first argument. This pointer opens up Lua. The `lua_open` command (introduced in Chapter 6) is what fires up the Lua state. All API functions need to set `lua_open` up as their very first argument.

In order to use `lua_open` in a C environment, the lua.h file must be included. The lua.h file is a C header file that defines the Lua API. However, since Lua is ANSI C, any inclusions of the Lua library must be wrapped within an `extern` C command, otherwise the compiler will mangle the names and not be able to call the commands properly. This may sound complicated, but in practice it looks like this:

```
extern "C"
{
#include <lua.h>
}
```

Name Mangling

Compilers have a habit of modifying the names of functions and objects when compiling. This is done so that the compiler can include extra information, provide type linkage, and support function overloading. This modification is often called *mangling*. Particularly confusing is that each compiler has its own way of mangling names and laying out the compiled objects. This can cause problems when working with more than one language, as a second language cannot predict how a particular object or command may be mangled. Luckily, the `extern` command can be used to disable name mangling entirely.

When the Lua state machine is finished with its job, it should be closed using the `lua_close()` command. This command destroys all objects in the given Lua state via the garbage collector. Therefore, a full instance of Lua wrapped within C code looks something like this:

```
extern "C"
{
#include <lua.h>
}
lua_state *Mylua lua_open (0)
// Many lines of
```

```
// Useful Lua code that
// Do something
lua_close (MyLua)
```

More or less, every function in the Lua API deals with the Lua state or the current state of the Lua interpreter (you will often hear Lua being referred to as a "state machine" when used in this way). The Lua state keeps track of functions, globals, and any interpreter-related information. When the Lua state is closed, all the Lua objects and any dynamic memory used by the state are freed.

> **NOTE**
> On some platforms, you may not need to call the close state, because resources are released normally when the program ends. Long-running programs or daemons may need to be released occasionally.

Whenever Lua calls C, the called function gets a virtual stack. This stack contains any arguments to the C function, is used to pass values to and from C, and will hold any values the C functions push back. Stacks can hold more than one element and are represented by an index, the top element of which can be called with `lua_gettop`:

```
Int lua_gettop (lua_State *L);
```

Stack Commands

Lua uses a stack to pass values to and from C. Each element in this stack represents a value (`nil`, `number`, and so on) that Lua uses. The Lua API offers a number of useful commands for manipulating the stack, querying stack functions, and translating C to Lua. These commands are listed and summarized in Table 7.3.

Stack commands are normally given as arguments to the `lua_State`, a pointer to Lua (`*Lua`), and/or the appropriate index in the stack. Push functions receive a C value, convert it to a corresponding Lua value, and then push the result onto the stack.

The Lua stack is is the primary means of communication between C and Lua. There are no Lua type values in C, only functions that manipulate the stack. All values, functions, and so on are pushed onto or pulled from the stack.

Variables

Lua variables in the API do not need to be declared, and by default are considered global in scope unless specified otherwise. The variables that store Lua values are global values, local values, or table fields.

Local values can be declared anywhere within a block or chunk of Lua code. They are lexically scoped. This means the scope of variables begins at the first statement after their declaration and lasts until the end of the innermost block that includes the declaration.

TABLE 7.3 Lua API Stack Commands

Command	Type	Purpose
`lua_concat ();`	`void`	Concatenates the values at the top of a stack, pops them, and leaves the result at the top
`lua_equal ();`	`int`	Compares two items on the stack
`lua_insert ();`	`void`	Moves the top element to a given index
`lua_isboolean ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_iscfunction ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_isfunction ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_isnil ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_isnumber ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_istable ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_isstring ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_isuserdata ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_islightuserdata ();`	`int`	Returns 1 if the object is compatible, otherwise 0
`lua_lessthan ();`	`int`	Compares two items on the stack
`lua_pushboolean ();`	`void`	Pushes Boolean value onto the stack and returns a pointer to the Boolean
`lua_pushcfunction ();`	`void`	Pushes a C function onto the stack and returns a pointer to the function

Continued

`lua_pushfstring ();`	`void`	Pushes a formatted string onto the stack and returns a pointer to the string
`lua_pushlightuserdata ();`	`void`	Pushes light user data onto the stack and returns a pointer
`lua_pushlstring ();`	`void`	Makes an internal copy of given string, pushes, and returns a pointer to the string
`lua_pushnil ();`	`void`	Pushes a `nil` value onto the stack and returns a pointer to the value
`lua_pushnumber ();`	`void`	Pushes a numeric value onto the stack and returns a pointer to the number
`lua_pushstring ();`	`void`	Pushes proper C strings onto the stack and returns a pointer to the string
`lua_pushvalue ();`	`void`	Pushes a copy of an element to a given index
`lua_pushvfstring ();`	`void`	Pushes a string onto the stack and returns a pointer to the string
`lua_rawequal ();`	`int`	Compares values for primitive equality
`lua_remove ();`	`void`	Removes element at the given index
`lua_replace ();`	`void`	Replaces given index with given element
`lua_settop ();`	`void`	Sets the stack top to a given index
`lua_State`	`struct`	Dynamic structure that holds all Lua states
`lua_totrhead();`	`int`	Converts a value on the stack into a C thread
`lua_strlen ();`	`int`	Gets a string's length
`lua_tocfunction ();`	`int`	Converts a value on the stack into a C function
`lua_tonumber ();`	`int`	Converts a Lua value at given index to a C type number. Number is a double by default
`lua_tostring ();`	`const char`	Converts a Lua value at the given index to a C type string (in C a `const *char`)
`lua_touserdata ();`	`void`	Translates userdata to a specific C type
`lua_type ();`	`int`	Returns the type of a value in a stack

All global variables exist as fields in ordinary Lua tables called *environment tables* or simply *environments*. Functions written in C and exported to Lua all share a common global environment. Each function written in Lua has its own reference to an environment, so that all global variables in that function refer to that environment table. When a function is created, it inherits the environment from the function that created it.

Userdata

Userdata is used to represent C values. Lua supports two types, full userdata and *light* userdata. Full userdata represents a block of memory and light user data represents a pointer. Both are considered objects.

The `lua_type` command will return `LUA_TUSERDATA` for full userdata or `LUA_TLIGHTUSERDATA` for light userdata when checking an existing userdata. New userdata can be created with the `lua_newuserdata ()` function:

```
void *lua_newuserdata (lua_stat *MyLua, size_t size);
```

This allocates a new memory block, pushes onto the stack a new userdata with the block address, and then returns the address.

Tables

The Lua API also has a few functions for manipulating metatables in objects. You create tables by calling the function `lua_newtable`. This function creates a new, empty table and then pushes it onto the stack. The function `lua_gettable` is provided for reading a value from a table that resides somewhere on the stack; when `lua_gettable` is given an index that points to the table, it will read and return the value.

Interestingly, in the Lua API, all global variables are kept within the ordinary Lua tables called environments. The initial environment that is created is called the global environment, and it can be pseudo-indexed at `LUA_GLOBALSINDEX`. Regular table operations can be used over an environment table to access and change these global values (using `lua_pushstring`, for example). The global environment of a thread can be changed using `lua_replace`.

The `lua_getfenv` and `lua_setfenv` functions are used to get and set the environment of Lua functions. First `lua_getfenv` pushes the environment table of the function on the stack at a given index, and then `lua_setfenv` pops a table from the stack and sets it as the new environment for the function at a given index.

There are a number of other useful Lua functions for dealing with tables. `Lua_getmetatable` pushes the metatable of an object on the stack, and `lua_setmetatable` sets the table on the top of a stack as a new metatable for that object and then pops the table. The `lua_load` command is used to load up Lua chunks. It automatically detects whether a chunk is text or binary, and then loads it accordingly.

```
int lua_load (lua_State *MyLua, lua_reader, void *Mydata, const char *MyChunk);
```

The function `lua_rawget` gets the real value of a table key. To store the value into a table that resides somewhere in the stack, the key and the value are pushed by calling `lua_settable`. The `lua_rawest` function is used to set the real value of any table index. Tables can be traversed with int `lua_next`, which pops a key from the stack and pushes a key-value pair from the table. If there are no more elements left, then `lua_next` returns a 0.

Tables are created by calling `lua_newtable`:

```
void lua_newtable (lua_State *MyLua);
```

Reading the value in a table on the stack is done by calling the `lua_gettable` command with a specific index:

```
lua_gettable (lua_State *MyLua, int specific_index);
```

Because of their universality and flexibility, tables are often used as arrays in the API.

TIP

Some of you C buffs are probably wondering how Lua handles arrays. Lua does have functions to work with C arrays, which are treated as Lua tables and indexed by numbers. Lua basically turns Lua tables into arrays indexed by number keys. The API uses two commands to accomplish this: `lua_rawgeti`, to push the value of elements into the table at a given stack position, and `lua_rawseti`, for setting the value of elements of a table at a given stack position. The `lua_getn` command is a third function that will get the number of elements in the table/array.

Threads

Lua offers partial support for multiple threads. Since the support is pretty basic, you will often find programs that instead incorporate an existing C library offering full multi-threading.

Adding a new thread to the Lua state can be done by using the `lua_newthread` function:

```
Lua_State *lua_newthread (lua_State *L);
```

The `lua_newthread` function pushes the thread onto the stack and then returns a pointer to `lua_State` that represents this new thread. All the global objects are then shared between the different threads, but this new thread has its own independent runtime stack. Each thread also has an independent global environment table.

Manipulating an existing thread can be accomplished by using the `lua_resume` and `lua_yield` functions, which allow one to suspend or resume running threads. Lua threads can be closed using the `lua_closethread ()` function.

Calling Functions

When C and Lua are working in tandem, both C and Lua functions can be called. For C functions to work, you must do the following:

1. Register the C function with Lua.
2. Push the function to be called onto the stack.
3. Push any arguments to the function onto the stack.
4. Call the function with `lua_call`.

The `lua_call` function looks something like this:

```
int lua_call (lua_State *MyLua, int arguments, int results);
```

The `arguments` and `results` integers are the numbers of arguments and results that passed onto the stack.

If a C function needs to keep a reference to a Lua value outside of its lifespan, it must create a reference to the value. These references are stored and manipulated and released with `lua_ref`, `lua_getref`, and `lua_unref`.

All arguments and the function value are then popped from the stack. Lua makes sure that the returned values fit on the stack, and that the function results are pushed in direct order so that the last result is on the top. The `lua_call` function propagates any errors in this process upwards, and a special function, `lua_pcall`, is used to track error messages that flow this way.

C functions can also be used to extend Lua, a technique that is covered in Chapter 12, along with extending Ruby and Python in the same way.

Performing Actions

Lua's C API has equivalent commands to the basic library that it uses when in C API mode. These commands are listed in Table 7.4.

Out of all of these, `lau_dostring` is the one most likely to be encountered because it is used to perform most Lua actions. Lua can also be executed in chunks written in a file or in a string by using `lua_dofile`, `lua_dostring`, or the `lua_dobuffer` command.

When called with a `NULL` argument, `lua_dofile` executes the standard in (`stdin`) stream. Both `lua_dofile` and `lua_dobuffer` are able to execute pre-compiled Lua chunks this way. The `lua_dostring` command, however, can only execute source code.

The function `lua_dostring` calls the interpreter over a section of code contained in a string. The `lua_getglobal`, `lua_setglobal`, `lua_call`, and `lua_register` are used to interpret code files, set and manipulate global variables, call Lua functions, and make C functions accessible to Lua.

TABLE 7.4 Lua API Actions

Basic Library Function	Equivalent C API Function
`dofile ()`	`lua_dofile`
`dostring ()`	`lua_dostring`
`error ()`	`lua_error`
`newtag ()`	`lua_newtag`
`tag ()`	`lua_tag`
`type ()`	`lua_type`

Summary

Lua's capabilities should be fairly clear at this point, and SDL has been tackled for the second time in this book. Here are a few important points before continuing to the next chapter:

- Blitting is still the key to rendering objects in SDL, whether using Python or Lua.
- Rects are still the key for blitting a sprite or object to the screen.
- The key to utilizing the C API is the stack.
- Tables in Lua are used everywhere. They make good containers for game objects and good containers for global variables in the C API.
- The most commonly found API function (after `lua_state` and `lua_open`) is `lua_dostring`.
- The Lua API functions are held within the `lua.h` header, which must be wrapped in a C `extern` command.

Questions and Answers

Q: *I can't seem to get the Gravity.lua code to work. Is there anything else I should try?*

A: Make sure you have the luaSDL.dll file somewhere on your system path. If you are using Windows, try this:

1.) Open up a command prompt: type `cmd` or `command` from the Run option on the Start menu.
2.) Navigate to the Gravity directory with the command line: use the cd command to change directories to cd MY DOCUMENTS\BOOK\CHAPTER 7\GRAVITY.
3.) Type `Lua.exe Gravity.lua`

Q: *Where can I learn more about the Lua API?*

A: Lua-users.org Wiki pages have a few good, short API tutorials:

http://lua-users.org/wiki/

There is also an API section in the online 5.0 Lua manual:

http://www.lua.org/manual/5.0/

Exercises

1. Make a copy of the Gravity.lua source code and try playing with some of the variables to see what happens. Change the width and height of the video screen, change the number of player lives, and mess with the gravity and speed constants. What would you add or change to make the game more interesting or fun?
2. Take a look at the *Meteor Shower* game that comes bundled with the LuaSDL after you have a pretty good feel for *Gravity* to see what an even more complex Lua game looks like. Again, make some changes to the constants and variables. See if there is anything you would change to make the game more interesting or fun.
3. Take a few of the simple Lua code samples from the last chapter try to re-script them using the C API.